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Analysis of influence of mechanical boundary conditions on zero point shift of Coriolis flowmeter

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Abstract

Coriolis flow meters determine mass flow rate by measuring the phase shift of the signal pick-up coils. Therefore, changes in the phase shift amount not related to the flow of the measured medium cause mass flow measurement errors. The article is devoted to the experimental evaluation of the effect of mechanical boundary conditions of the Coriolis flowmeter on zero point shift. Special equipment, allowing changing the stiffness of the pipeline, to which the flowmeter is attached, has been developed. Modal experiments on the Coriolis flowmeter without liquid for different lengths of pipe have been conducted. It has been found out that the maximum zero point shift is observed when the frequency of natural vibrations of the coupled system of the flow meter and piping tubes coincides with the drive frequency of tube vibrations. Tests to assess the influence of external vibration on the zero point shift have been conducted. The maximum zero point shift is observed in the coincidence of the external vibration frequency with the drive frequency of oscillation of tubes.

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Keywords: Coriolis flowmeter; zero point shift; experimental modal analysis; external vibration; steady forced oscillations.

1. Introduction

A Coriolis flowmeter is used for measuring mass flow of liquids and gases. The overview of designs of Coriolis flowmeters is given in [1-3]. The flowmeter shown in Fig. 1 consists of a body 2 and two arranged inside it U-shaped vibrating tubes 3 through which the measured fluid flows. Drive coil 4 is used to excite steady forced oscillations tube at the resonant frequency. The shape of the steady forced oscillations is a movement of the tubes in

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the opposite direction to each other from the XY plane. The translational motion of the liquids in the rotational motion around the X axis gives rise to the Coriolis acceleration and thus Coriolis force. This force is directed against the movement of the tube, given it by the coil, i.e., when the tube moves along the Z-axis, for the fluid flowing inside the Coriolis force is directed against the axis Z. The direction of the Coriolis force is contrarily reversed as soon as the liquid passes the tube bends. In Fig. 1 the tube bends correspond to the position of the motion sensors 5 and 6. Due to the action of the Coriolis force there is a shift of the phases of mechanical vibrations of two tubes in the places of installation of motion sensors proportional to the mass flow rate. A detailed description of the principle of operation of the Coriolis flow meter is given in [4].

The Coriolis flowmeters determine mass flow rate by measuring the phase shift of motion sensors signals. Therefore, changes in the phase shift amount are not related to the flow of the medium, lead to mass flow measurement error.

The zero point shift of the Coriolis flow meter is the value of the phase difference without the flow of the medium. It is about 1000 times less than the desired phase shift of the nominal flow. But it is essential with 0.1% accuracy of the sensor. Each flowmeters is characterized by a zero point shift, the value of which is individual and determined at the stage of the device manufacturing.

One of the features of the Coriolis flowmeter is that the attachment of the meter to the pipeline can lead to a zero point shift. In this case, phase value after installation is taken for the zero shift. Less common, but more dangerous, is a situation of unstable zero shift of an installed flowmeter, when it changes over time leading to uncontrolled growth of mass flow measurement error.

This article examines the influence of the mechanical boundary conditions of the Coriolis flowmeter to a zero point shift. To do this, the experimental modal analysis of a coupled the meter-piping system for different lengths of pipe has been conducted. An experimental evaluation of the influence of external vibration on the flowmeter zero shift has been conducted.

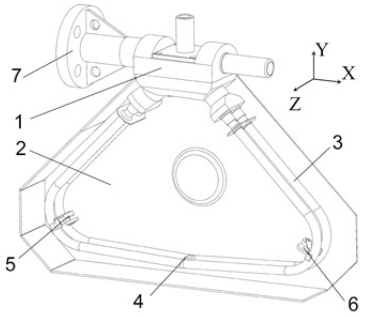

Fig. 1. Coriolis flowmeter:
1 - basis; 2 - housing; 3 - tube; 4 - drive coil; 5, 6 - motion sensors; 7 – flange.

2. Modal tests

To study the effect of various fixing conditions on the zero point shift there has been designed and manufactured a special equipment, allowing to change the stiffness of the pipeline by changing its length. These accessories are shown in Fig. 2. They consist of a base 1, which is a channel, and two tubes 2 with flanges welded on one end. The flowmeter 3 is attached by bolts to the flanges on the pipes. The tubes are joined by means of two fixed clamps 4 on the ends of the device. Movable clamps 5 run along guides 6. With two movable clamps the lengths of pipes L_1 and L_2 are changed.

The equipment is estimated with the impact of the lengths of pipes L_1 and L_2, to which the meter is attached, on a zero shift. Changing the length of the tubing affects the modes of the coupled flowmeter-piping system. To track the changes of these modes there have been held modal tests with different lengths of a pipeline.

Modal testing of the flowmeter, connected to the pipeline, was held on the flowmeter without liquid and with turned-off electronics (no excitation at the drive frequency). Firstly, there was a preliminary modal testing with lengths of pipe from 20 to 250 mm with a 50 mm increment. Then there were found the lengths at which the modal